Importance of Small Ice Crystals to Cirrus Properties: Observations from TWP-ICE

Research Highlight

Cirrus covers approximately 20% of the Earth's surface and is almost exclusively composed of ice crystals. To represent cloud feedbacks in global climate models and to improve predictions of climate change, cirrus effects on radiation must be quantified. At a microphysical level, the ice water content and ice crystal sizes and shapes are most important for determining how cirrus impacts radiation. One controversial and unsolved problem is quantifying the contributions of small ice crystals (crystals with maximum dimension $D < 50$ μm) to the mass and radiative properties of cirrus.

During the U.S. Department of Energy Atmospheric Radiation Measurement Program (ARM) sponsored Tropical Warm Pool-International Cloud Experiment (TWP-ICE), ice crystals with $3\ \mu m < D < 50\ \mu m$ were measured in aged cirrus and fresh anvils by a Cloud and Aerosol Spectrometer (CAS) and a Cloud Droplet Probe (CDP). Both the CAS and CDP detect the amount of light forward scattered by particles within the sample volume and use the same look-up table to convert scattering intensity to particle size. The probes differ in that the CAS has an inlet and a protruding airflow shroud, whereas the CDP has none. The CAS/CDP ratio of the number concentrations of droplets with $3 < D < 50$ μm, N[3-50], averaged 0.98/0.69 in liquid clouds hence showing that the probes were behaving identically in liquid clouds. However, N[3-50], measured by the CAS averaged 91-127 times larger than N[3-50] from the CDP in ice clouds (image). The CAS/CDP N[3-50] ratio had a correlation coefficient of 0.387 with the concentration of particles with $D > 100$ μm measured by the Cloud Imaging Probe, suggesting that ice crystals may have been shattering or bouncing on the CAS inlet or protruding airflow shroud enhancing N[3-50,CAS]. During the Costa Rica Aura Validation Experiment N[3-50,CAS] measured by a CAS without an airflow shroud were an order of magnitude less than those observed during TWP-ICE. This, and estimates of the maximum shattering based on the inlet and shroud sizes, suggest that the airflow shroud used during TWP-ICE was responsible for much of the shattering or bouncing. The differences noted between the CAS and CDP during TWP-ICE are significant because the total number concentration could be overestimated by 300%, extinction by 106%, and ice water content by 49% if shattering or bouncing explains all the observed discrepancies.

Because many previous parameterizations of particle sizes in cirrus have been developed using data collected by forward scattering probes with shrouds or inlets, this study has significant implications for understanding cirrus radiative effects.

Reference(s)

McFarquhar, G.M., J. Um, M. Freer, D. Baumgardner, G.L. Kok and G. Mace, 2007: Importance of small ice crystals to cirrus properties: Observations from the Tropical Warm Pool International Cloud Experiment (TWP-ICE). Geophys. Res. Lett., 34, L13803, doi:10.1029/2007GL02986

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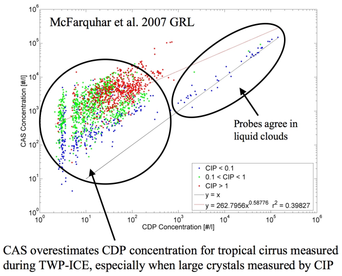
Cloud Properties



Scatterplot of ice crystal number concentration from the CAS and CDP probes during TWP-ICE.